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Regulated Light Source

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The light output from a small incandescent lamp can be regulated by employing a photoconductive cell in a feedback loop. Two systems are described and analyzed. Drifts less than 0.07% are achievable.

INTRODUCTION

THE need frequently exists for a regulated or stabilized light source in certain photodensitometry studies. Small changes in light transmission of a test cell must be resolved and having a stabilized incident source simplifies the procedures. It is generally possible to refer to a preset level prior to a measurement or use a double beam scheme and refer to the secondary beam. However, these techniques are sometimes awkward when long time runs must be made. The output of an incandescent light source will vary with the voltage raised to the 3.5 power and small variations in line voltage can change the light output significantly. With constant voltage supplied to a lamp, there will be an initial aging period followed by a slow decline of light output due to metal evaporation onto the glass enclosure. These changes vary with lamp construction and design and the No. 63, 3 candlepower lamp, was selected for its most constant light output, based on manufacturer's recommendations.

Superimposed on the long term downward drift of light output is a faster "noise" variation. This noise component of the light output can be mechanical or electrothermal in origin. By examining the magnified image of a lamp filament, temperature gradients are clearly visible. The coolest portion is the outside surface of the coil windings and the inside is the brightest and hottest. As filament turns physically move, temperatures are redistributed and the integrated light output can change. It is also possible that there will be a reaction on the power supply due to a change in resistance. A constant voltage source with a positive temperature coefficient filament will result in a self-regulatory system due to degenerative electrothermal feedback. A closed loop regulating system can minimize all output light variations.

THEORY AND APPLICATION

By employing a cadmium sulfide[1] photoconductor cell as a sensor, it is possible to monitor the light output in the form of a resistance variation and use this resistance to regulate the voltage. The resistance can be sensed in a bridge circuit and the error amplified to ultimately control the lamp output. As another procedure, it is possible to use a "programmable" power supply wherein the output voltage varies with the injected resistance.[2]

Consider the circuit shown in Fig. 1. The lamp is driven by a double emitter follower from the unregulated 15 V supply. A Wheatstone bridge circuit contains the CdS cell as one arm and the error voltage is amplified and direct coupled to the lamp driver circuit. A Zener regulator feeds the bridge and amplifier circuits since this is the critical sensing portion of the circuit. By adjusting R_1 it is possible to unbalance the bridge and set the initial light output level.

With no illumination on the light cell, the output voltage is a maximum (i.e., 10 V) and as the cell resistance falls with illumination, the output voltage also falls. The entire characteristic of the bridge amplifier circuit can be described as

$$v_0 = V_0 - sg, \tag{1}$$

where v_0 is the output voltage, s is a sensitivity in volts per mho, and g is a photocell conductance. The lamp light output is approximated as

$$\lambda = av_0^n, \tag{2}$$

where a is a constant, v_0 is the lamp voltage, and the exponent n is roughly 3.5 in the normal operating region.

The cell conductance varies nearly linearly with λ (actually close to the 0.9 power); or

$$g = b\lambda = abv_0^n, \tag{3}$$

where b includes cell geometry and location factors.

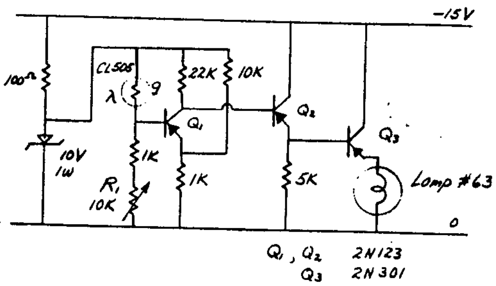

FIG. 1. A circuit diagram of the simple transistor regulator circuit is shown. Since the circuit is direct coupled it is important that electrical and thermal stability be good.

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[1] See Clairex Corporation Bulletin 50CL264A.

[2] P. Berman, Electronic Ind. 23, 47 (1964).

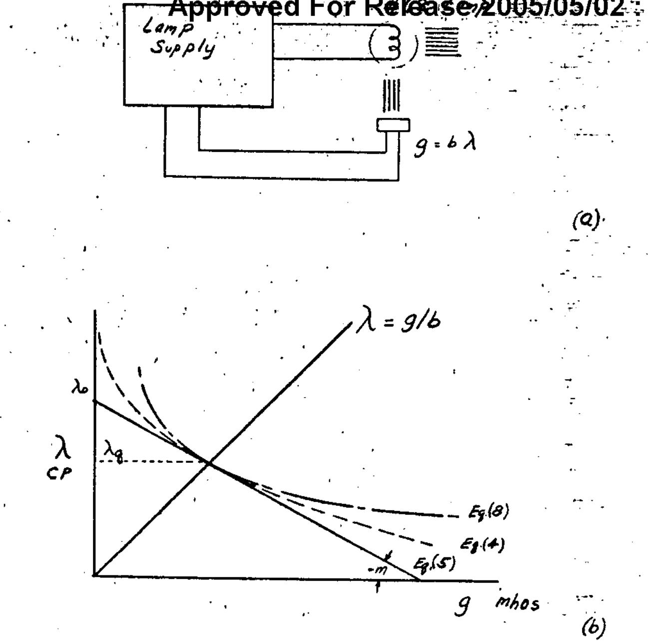

Fig. 2. The control loop is shown (a), together with a graphical interpretation of the operating point (b). The photocell characteristic ($\lambda = g/b$) intersects the lamp supply characteristic Eq. (4) or Eq. (8) which are replaced by the linear approximation Eq. (5).

Solving these equations for the light output the result is

$$\lambda = a(V_0 - b\lambda s)^n; \tag{2a}$$

this equation is not in a useful form, although it does represent the operating point solution. Figure 2(b) graphically indicates this solution for the feedback loop shown in Eq. (2a). The supply-lamp characteristic is

$$\lambda = a(V_0 - gs)^n, \tag{4}$$

where g is the independent variable. Similarly the cell characteristic is $\lambda = g/b$. In the vicinity of the operating point, the supply-lamp characteristic can be represented as the linear variation

$$\lambda = \lambda_0 - mg, \tag{5}$$

$$m = d\lambda/dg = -ans(V_0 - gs)^{n-1} = -\lambda_q ns/(V_0 - gs), \tag{6}$$

evaluated at the operating point ($\lambda = \lambda_q$). This light level is

$$\lambda_q = \lambda_0/(1 + mb),$$

and its sensitivity to a change in m is

$$d\lambda/dm = -\lambda_0 b/(1 + mb)^2. \tag{7}$$

the product mb must be large to provide the best stability and m depends on several factors. A sudden change in lamp efficiency a will be minimized by a large mb product.

Next, consider the application of a programmable power supply for this application. Now the power supply characteristic is $V_0 = k/g$, where k is in volts per ohm. As an example, for a particular power supply[3] the program characteristic is 1 volt per 100 ohms, corresponding to $k = 10^{-2}$. The light output characteristic is

$$\lambda = a(k/g)^n \quad \text{or} \quad \lambda^{n+1} = a(k/b)^n, \tag{8}$$

and it is an hyperbola as shown in Fig. 2(b). A similar analysis applies now where

$$m = d\lambda/dg = -an(k/g)^n/g = -n\lambda_q/g. \tag{9}$$

A large value of m is again required. By adjusting b, the light cell coupling to the lamp, it should be possible to set the initial light level. It is also possible to pad the programming characteristic with resistance or select a cell which will be compatible with the required lamp voltages for near normal output (λ_q).

EXPERIMENTAL OBSERVATIONS

Figure 3 is a recording of the light output under various conditions. Light was measured by means of a photovoltaic cell. It is important to note that these cells are temperature sensitive due to the internal leakage or shunting resistance. A small load resistance minimizes this temperature sensitivity at the expense of output level. Variations of the order of 1% per 5°C are possible.

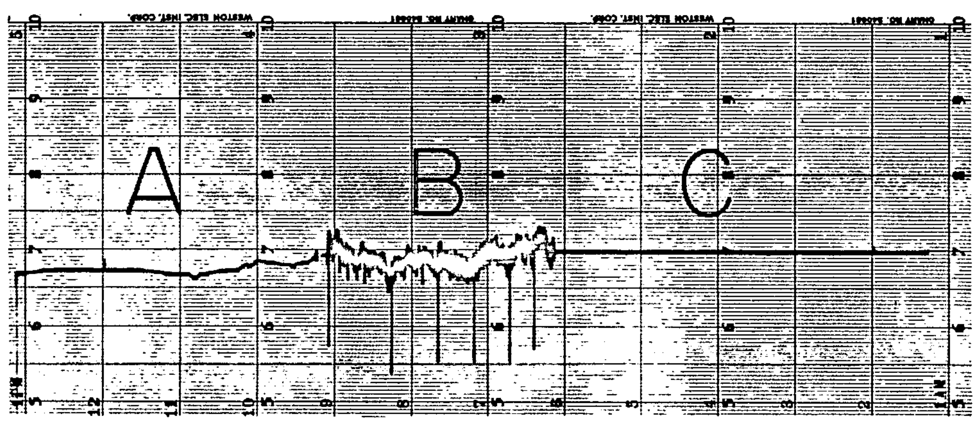

Fig. 3. Observed light output characteristics as measured with a photocell are recorded (10 min/box) for (A) a regulated voltage source; (B) an unregulated supply; and (C) the circuit of Fig. 1.

[3] Harrison Laboratories PS# 855 or equivalent; 0–18 V, 0–1.5 A.

Region A corresponds to the lamp on a commercial regulated power supply and the variations in λ are apparent. Region B is for an unregulated power supply set at 6 V. In Region C, the unregulated power supply is set at 15 V and supplied to the lamp via the light regulator of Fig. 1. The light regulation is good. The best system resulted from using the regulated commercial power supply in a programmable manner as described. Total variations of less than 0.07% were observed after an initial warm-up period of about one hour. The regulator must come to thermal equilibrium after which the largest source of variation was due to mechanical position changes and photocell temperature variations. The CdS cells employed have negligible resistance-temperature variation in the regions used (i.e., 5% for 25°C variation). It can be expected that temperature control of the regulator circuit as well as improved mechanical stability will result in more improved regulator performance.

ACKNOWLEDGMENT

The capable assistance of Donald Davis in assembling and testing the systems described is gratefully acknowledged.

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Simultaneous Measurements of Optical Transmission and Reflection in Thin Films*

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A monochromator modification was developed which makes simultaneous measurements of the optical transmission and reflection of thin films deposited in vacuum. The measurements can be made with light incident from either the substrate of the film or from the vacuum interface. The instrument is capable of working in the 0.4 to 2.30 μ wavelength range. The measuring system, sample design, and experimental errors are discussed.

INTRODUCTION

THE measurements of transmission and reflection spectra of thin evaporated layers have been performed previously in two separate measurements.[1] In many experiments simultaneous monitoring of the transmission and reflection properties of a thin layer is required. Such measurements are necessary, e.g., if the layer changes its optical characteristics.

In our work a system was designed and tested which can be adapted to standard monochromators, and which enables one to measure transmission and reflection spectra of thin films deposited on flat, transparent substrates or in specially shaped evacuated chambers.

DESCRIPTION OF APPARATUS

The monochromator utilized in our experiment was a Perkin-Elmer type 99 providing a constant energy, 13-cycle chopped monochromatic light beam at its exit slit. The unit which we adapted for measuring transmission and reflection spectra was the modification of the Perkin-Elmer "transfer optics."

The P-E transfer optics consist of two first-surface flat mirrors and a first-surface spherical mirror arranged as shown in Fig. 1 to produce an image of the exit slit in free space about 20 cm from the monochromator. This arrangement would permit the monochromatic light to pass symmetrically through a sample. The light is then collected by an elliptical mirror and its intensity is measured by the thermocouple detector (D_1).

As the monochromator has an internal reference thermocouple detector which is used to provide a constant energy output, the readings obtained at the thermocouple detector D_1 can be used directly to measure the transmission spectrum of materials placed in the path of the beam.

The modification of this system is also shown in Fig. 1. The system shown there enables one to measure reflection as well as transmission spectra of thin evaporated layers

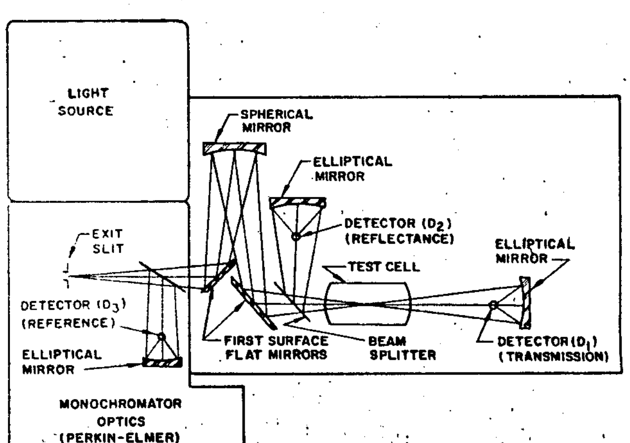

FIG. 1. Monochromator modification schematic.

* The research reported in this paper was sponsored by the U. S. Army Engineer Research and Development Laboratories, Fort Belvoir, Virginia, under Contract number DA-44-009-AMC-442(T).

[1] W. E. Spicer, Phys. Rev. 112, 114 (1958).

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Scanner-Prenormalizer not usable in its present design & configuration

1. Light source behind the slits cannot achieve a balanced output, cannot not match the amplitude, all lamps are slightly different & each varies in output (possibly because of filament vibration)
have tried both gas lamps & incandescent lamps

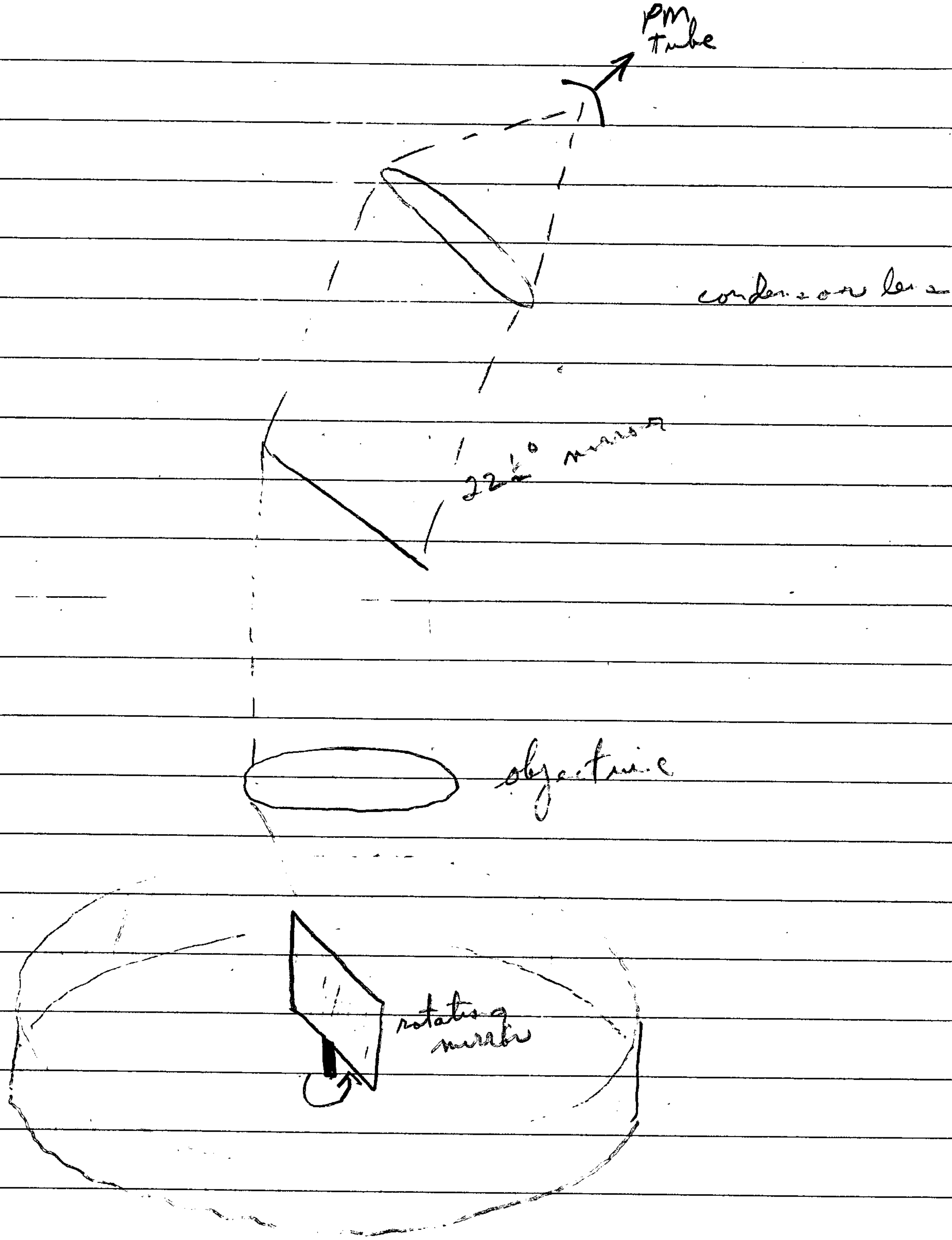
2. The optical alignment is extremely poor due to poor optical design.
Primary design deficiency is that the various mirrors & lenses do not have provisions for X-Y adjustments, therefore they are "locked" in their designed position.
It seems that the design was done by a mechanical designer who had very little experience with optics. They only recently acquired an optical designer. The scanner can be rebuilt but they are questioning the cost vs value at this time. ~~[illegible]~~

3. To complete their testing on the old contract before 30 Sept they are resorting to the "old" concept of the rotating line scan on A CRT. w/ a rotating dove prism.
This still uses the line integral scan theory but not the designed hardware.

3000 TV lines / inch westinghouse tube
3" tube ~ 60 ll/mm

4. Conflex will be returned to WPAFB 30 Sept.

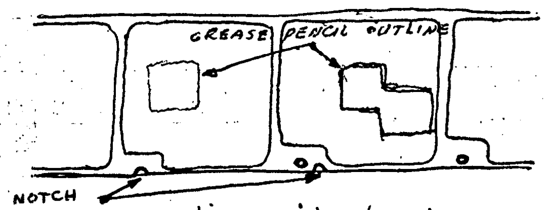
Computer simulation (G.15) much slower than conflex.


PM tube
condensor lens
22½° mirror
objective
rotating mirror

Dick --

In the can is the roll of positive film you sent us. The frames to be enlarged are marked in two ways

1. To signal the frame for the operator a circular notch has been punched in the edge in the frame marking block. For other purposes, a complete hole was punched ~~inside~~ inside the block, but only those with a notch need be enlarged.



(emulsion side down)

2. The portion of the frame to be enlarged has been outlined in grease pencil on the ba
On some frames there are overlapping enlargement areas.

A band of masking tape was placed across the film just before frame 46941 to signal the start of the run. Frames 46941 thru 46972 require a 2.94 enlargement. The make line, ~~scratched~~ scratched between frames 46939 and 46940 is 0.615" long. Blow it up to ~~1.816~~ 1.81 inches. The marked areas are approximately 1.5" square; the enlarged negative can then be made on 5" film.

The next group of enlargements (from frames 47219 through 47297) require the same blow-up: ~~3x~~ 3x. A make line 0.553" long is scratched ~~at~~ at the front edge of frame 47219 and another one 0.565" long between frames 47260 and 47261. These should enlarge to 1.659" long and 1.695" long respectively.

This set of ~~enlargemen~~ enlargements will be negatives at approximately 1:5,000 scale. We need positives at two scales – 1:5,000 and 1:2,500 for our "tactical" targets. Therefore the resulting enlargements must be contact printed and then enlarged 2× to provide the imagery we need.

In the glassine envelopes are approximately 60 contact negatives from the positive roll you sent us. These are made on 4"×5" commercial film. Please reduce as shown on the envelopes to ~~produce approximately~~ 1:25,000 positive imagery required for our "strategic" targets. Sample print-back positives from these negatives ~~are~~ onto ~~Return~~ fine-grain positive film are included.

Return the original 5" film (if possible) or the negatives on commercial film with the other work.

Thanks

STAT

P.S. I am available for photo assistance in your lab if you need me for this job.